

FISHERY INVESTIGATIONS

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**Developments in the laboratory
culture of the common prawn,
Penaeus serratus Pennant**

N F. WICKINS

Marine Fisheries Research Station, Conway

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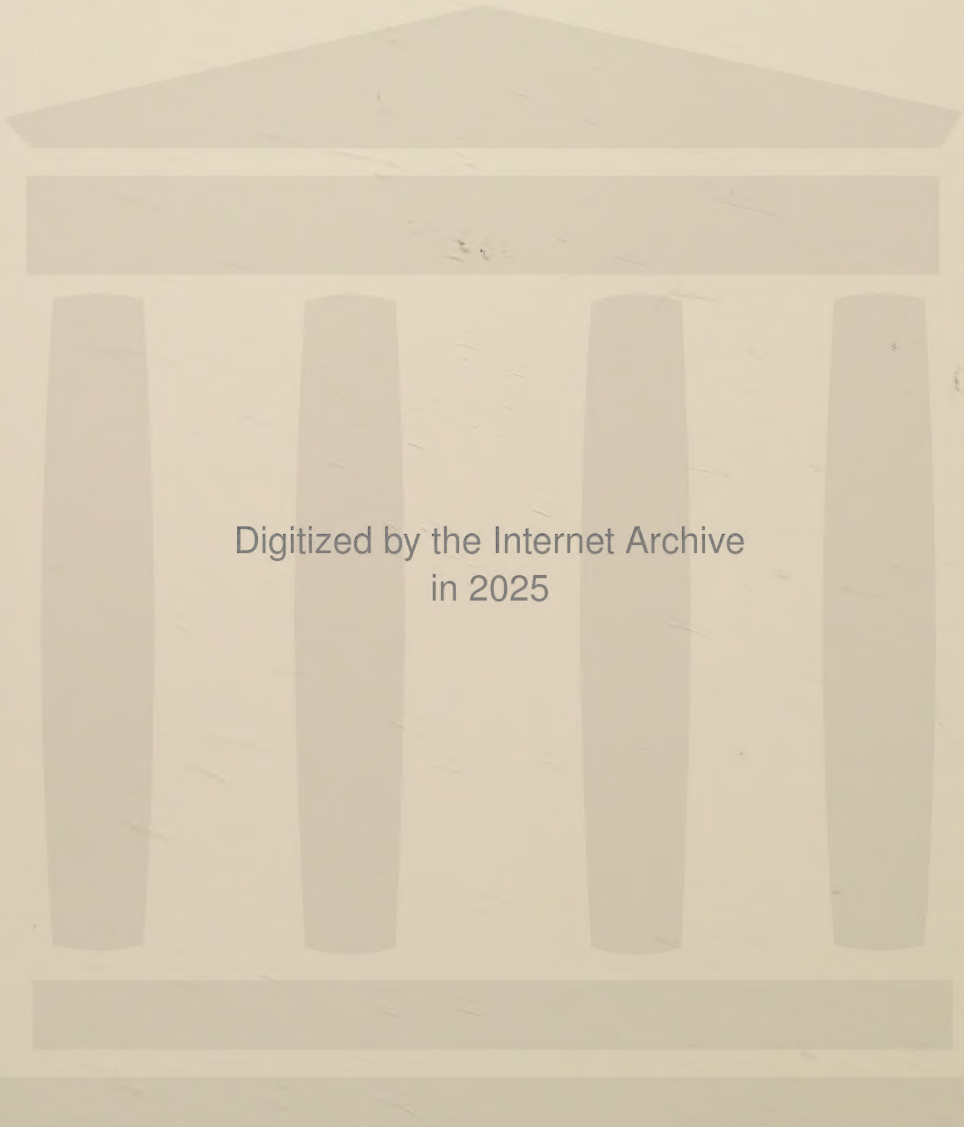
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Abstract

The prawn *Palaemon serratus* Pennant was cultured through four generations in captivity. An account is given of the influence of culture hygiene, illumination, food quality and seawater temperature on the growth of the larval stages. The results showed that the larvae were particularly hardy and adapted well to laboratory conditions.

A number of post-larval prawns were cultured continuously for 15 months and the effects of population size and sex ratio on their survival and growth were studied.

The present Fisheries Research Board of Canada report is a summary of the results of the investigations of the effects of the various factors on the growth and survival of the young of the fish. The results of the investigations are presented in the form of a series of tables and graphs. The results of the investigations are presented in the form of a series of tables and graphs.



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Introduction

Studies made at this laboratory (Reeve 1969*a*, Forster 1970*a*) have described methods by which the prawn *Palaemon serratus* Pennant can be reared in captivity throughout its life cycle; these studies introduced the possibility of commercial prawn culture in the United Kingdom. The experiments reported in this paper were designed to amplify some of the factors which were thought to have an important influence on the culture of both larval and post-larval stages of this species.

Methods

SELECTION OF PARENT STOCK

ovigerous prawns were purchased from time to time in batches of 100 animals—from fishermen at Lymington and Lyme Regis (Dorset), Par (Cornwall) and Loughmoe (Co. Cork). They were transported by road to the laboratory in polythene dustbins containing about 40 litres of sea water. Splashing was reduced by baffles—in the form of a stack of half-round PVC sheets held together by cords—fixed at the bottom of the bins. The journey from the sea to the laboratory lasted from 6 to 14 hours and, during this time, oxygen from a cylinder was bubbled through the water to maintain a satisfactory level of dissolved oxygen. Prawn stocks were transported in this way survived well and mortalities did not exceed 5 per cent. Occasionally prawns were collected in Holyhead harbour (Anglesey).

SELECTION OF LARVAE

Prawns bearing eggs at an advanced stage of development were transferred to tanks with a supply of running sea water. The tank overflows were arranged so that when the larvae hatched the current of water carried them into a separate collection tank, usually an 8 litre polythene bucket. This facilitated handling and prevented predation by the adults. The larvae were confined to the bucket by a filter, made from a 5.5 cm length of 6 cm diameter PVC pipe fixed at both ends with nylon mesh (280 μ m), which was placed inside the bucket over the end of the outlet pipe (Plate 1). In this way single broods of larvae were isolated ready for use in the small-scale experiments made in 1 litre beakers. For larger numbers or mixed broods of larvae were required, either several females were placed in one tank or the larvae from several collection tanks were pooled.

SELECTION OF EXPERIMENTAL ANIMALS

Selection of larvae: Experiments with larvae were made in 1 litre hard plastic beakers. In early trials up to 100 larvae per litre were used. These numbers were later reduced to 10, 20 or 25 per litre so that their feeding activity would not reduce the concentration of food organisms—*Artemia* nauplii—too quickly. Usually two, but sometimes three or four, replicate populations were used in each experiment, and, except where stated in the tables, the mean result of each set of replicates is reported.

Temperature: Most of the experiments were made in the temperature range of 21–23°C, which occasionally increased to 20–24°C. Most of the beakers stood in a water bath for temperature control and in this situation they received some natural light as well as continuous artificial light; others stood on shelves in a controlled temperature room where they received only continuous artificial illumination. Each day any dead food organisms were removed with a pipette and fresh food was added to maintain the required level. Two or more times a week the water and food in the vessels were renewed.

Feeding: Larger numbers of larvae were cultured in black polythene dustbins containing 60–65 litres of sea water. The water aeration, which was supplied from a single nozzle to

all cultures, was sufficient to keep larvae and their food in suspension but it was not so vigorous as to prevent the larvae from catching their prey.

Post-larvae: Vessels in which post-larvae were held included 400 litre fibreglass tanks (126×55×61 cm deep), 50 litre white polythene tanks (57×37×25 cm deep), and 400 litre wooden tanks (120×120×30 cm deep) painted with two coats of a non-toxic brown paint. Stocks of prawns were kept indoors in fibreglass tanks provided with a flow of sea water recirculated from a 12 000 litre reservoir. These stocks were held at $16\pm 2^\circ\text{C}$ until required for experiments. The stocks were aerated to maintain a satisfactory level of dissolved oxygen in the water.

SEA WATER

In the text natural sea water refers to water taken at high tide from the Conway Estuary; some settlement of silt took place during its passage through storage tanks. Filtered water refers to natural sea water that had been passed through a plate filter containing diatomaceous earth which removed 90 per cent of suspended particles down to 2.5 μ m in size.

FOOD

Larvae were fed with the live nauplii of the brine shrimp, *Artemia salina* L., at a concentration of about 10 per ml (Reeve 1969a). Fresh food was supplied daily except in some of the earlier trials where it was given two or three times each week. When slightly larger *Artemia* (1.3–3.8 mm) were required these were cultured for three or four days, after hatching, in a suspension of the algae *Isochrysis galbana* Parke and *Tetraselmis suecica* (Kytlin) Butch.

The most satisfactory food for juvenile and adult prawns was found to be the flesh of the mussel *Mytilus edulis* L. It was provided in the form of freshly opened half shells which were placed among the prawns in the tanks. The remains of the previous day's food were removed each day before fresh mussels were added. In small-scale experiments pieces of *Mytilus* mantle tissue were added as food.

EXPERIMENTAL PROCEDURE

The experimental study of larvae was primarily concerned with finding ways to produce the greatest proportion of healthy post-larvae in the shortest possible time. The reactions of the larvae to the experimental conditions were observed, using the parameters of survival, length of larval life and growth. In this paper survival has been expressed as a mean percentage in order to accommodate experiments made with different numbers of larvae; the length of the larval life was taken as the age of a population when a known proportion were post-larvae, and growth has been defined in terms of measurements of length.

Experiments made with post-larval and juvenile prawns were concerned with factors that influenced their survival

and growth rates. Growth was expressed by length and weight measurements.

Measurements of length: Live larvae and immediate post-larvae were measured with a low-power binocular microscope fitted with a graduated eyepiece. Specimens were placed in a drop of water on the stage and manipulated into an extended position with a fine paint brush while the water was removed with a narrow bore pipette. Measurements were made from the tip of the rostrum to the tip of the telson (excluding uropods). After measurement the larvae were washed back into the culture vessel. This procedure, conducted with care, caused no apparent damage to the larvae. Live juvenile and adult prawns were measured by holding them against a graduated rule. This method was used in preference to the more precise method of Cole and Mistakidis (1953), since there was less risk of causing damage to

the prawns and particularly to small, very active, and newly moulted specimens.

Measurements of live weight: Individual prawns were moved from their containers with a mesh strainer and placed on several layers of absorbent tissue paper. A single piece of tissue paper was laid over the prawn which was then gently stroked with a soft paint brush to remove most of the external water. The prawn was then placed in a tared box and weighed. A series of repeated test weighings showed that this method gave reasonably consistent results. In the test, individual prawns—average weight 290 mg—were weighed five times within 24 hours. They were weighed to 0.1 mg and the standard deviation was 2.01 (Forster 1970b).

Populations of prawns were dried with absorbent tissue paper and weighed to the nearest 0.5 g on a top-loading balance.

Experimental Results: Larvae

RAL

larvae of *P. serratus* hatch from the egg, at a relatively early stage in their development, as free-swimming zoeae. Reeve (1969b) found that moulting occurred fairly regularly at three-day intervals and that some broods of larvae moulted after only five or six moults, whereas others moulted through as many as 11 moults before becoming post-larvae. The usual span of the larval life lay between 18 and 25 days.

CONDITION OF THE CULTURE MEDIUM

Cultures of marine larvae are particularly vulnerable to bacterial fouling. The most common agents responsible are bacteria and decaying food particles, excreta and microbiological growths. A series of small-scale experiments tested the effect of three methods commonly used for keeping cultures clean: (1) filtration of the sea water; (2) renewal of the sea water during the period of culture; (3) the addition of a suspension of antibiotics known to be effective in sea water.

Condition of the sea water: Reeve (1969a) reported that the survival of *P. serratus* larvae was less reliable in untreated sea water than in sea water treated by the method of Walne (1965). He found that the overall mean difference in the percentage survival between larvae reared in treated and untreated sea water was 5.3 per cent per week. In the following experiments larvae were cultured through to the post-larval stages. The experimental treatment differed from that of Reeve in that his filtered water had been irradiated with ultra-violet light, whereas that used in the present study was

79 per cent of the original numbers developed to the post-larval stage (Table 1). The treatment did not affect the duration of the larval phase—which lasted 26 to 36 days—or the proportion of post-larvae that developed ($P > 0.05$). Similarly 't' tests showed there were no significant differences ($P > 0.05$) between the mean lengths of the early post-larvae cultured in natural and filtered sea water (8.1 and 8.2 mm respectively). The wide range of sizes (7.3–9.0 mm) was due to one brood which produced post-larvae that, at 7.4 mm, were significantly smaller ($P < 0.05$) than the others (8.9 mm). It was concluded that under these conditions no advantage was gained by filtering the water (but see p. 12).

Frequency of changing: It is conceivable that the frequency with which larvae are transferred to fresh medium could affect their development. The rise in the numbers of bacteria in culture vessels at 20°C is likely to be rapid (Walne 1958) and frequent changes to clean medium could benefit the larvae; on the other hand, these benefits could be nullified by increased handling of the prawns. This possibility was tested in an experiment of factorial design in which two replicate populations of 25 larvae were used for each treatment. The larvae were cultured in either natural or filtered sea water and were transferred to new medium at either one- or three-day intervals. After two weeks' growth there were no significant differences ($P > 0.05$) between the mean lengths of the four groups of larvae, which ranged from 6.3 to 6.7 mm (mean 6.4 mm), or in the proportions which survived, 88–92 per cent:

Sea water	1 day between changes		3 days between changes	
	Length (mm)	% survival	Length (mm)	% survival
Natural	After two weeks			
	6.7	90	6.4	90
Filtered	6.3	92	6.3	88
Natural	After four weeks (post-larvae)			
	7.8		7.6	
Filtered	7.8		7.3	

Three trials were made with three different broods of larvae lasted from 26 to 36 days. Two replicates of 10, 25 and 25 larvae per litre were used in the three trials respectively. The culture media were changed at three-day intervals. Larvae cultured in natural and filtered sea water survived very well, 88.6 per cent and 82.0 per cent respectively, and

TABLE 1

The survival and growth of Palaemon serratus larvae cultured in natural and filtered sea water. Experiments A, B and C had 10, 25 and 25 larvae per litre and lasted 26, 30 and 36 days respectively. Figures in parentheses refer to individual replicates

	Experiment			Mean
	A	B	C	
Natural sea water				
Total percentage survival (larvae and post-larvae)	100 (100, 100)	86 (88, 84)	80 (80, 80)	88.6
Percentage of original population that became post-larvae	85 (80, 90)	80 (80, 80)	80 (80, 80)	81.6
Mean length of post-larvae (mm)	8.8	7.6	8.7	8.1
Filtered sea water				
Total percentage survival (larvae and post-larvae)	80 (70, 90)	78 (72, 84)	88 (92, 84)	82.0
Percentage of original population that became post-larvae	80 (70, 90)	68 (72, 64)	82 (80, 84)	76.6
Mean length of post-larvae (mm)	9.0	7.3	9.0	8.2

It was possible that the experimental treatments would affect the larvae more noticeably during metamorphosis. Accordingly they were cultured for a further two weeks until 98 per cent of the survivors were post-larvae; 74 per cent of the original larvae became post-larvae but there were no proportionate differences that could be significantly related to the treatments ($P > 0.05$). Similarly, the mean lengths of the early post-larvae in each group were not different ($P > 0.05$); these ranged from 7.3 to 7.8 mm (mean 7.4 mm). Likewise, the treatments did not appreciably alter the duration of larval life, which was 23 days. The average survival during the experiment was high, 78 to 86 per cent, which indicated that the environmental conditions were satisfactory.

The development of larvae in small-scale cultures was neither impaired nor improved by changes to fresh medium made more frequently than at three-day intervals. The same result was obtained whether natural or filtered sea water was used.

Antibiotics: Walne (1958) demonstrated that the yield of oyster spat was increased when 50 i.u. of penicillin G and 0.05 mg streptomycin sulphate per ml were added to cultures of the larvae and that this mixture suppressed bacterial

development for 9 days. He also found some evidence a higher concentration of streptomycin (0.25 mg per ml) the mixture was harmful to oyster larvae. Cook (1958) showed that the addition of these antibiotics during spawning and hatching of penaeid prawns retarded development of micro-organisms for 48 hours.

The effect of these antibiotics on the growth and development of prawn larvae was tested in two experiments with two replicate populations of 100 and 25 larvae respectively. The larvae were cultured for 30–36 days until a majority of the survivors, *c.* 95 per cent, were post-larvae. Apart from the different population sizes, the experimental groups were treated similarly. They were transferred to fresh medium at three-day intervals and the antibiotic mixture sufficient to give 50 i.u. of the sodium salt of penicillin and 0.05 mg streptomycin sulphate per ml, was added to the fresh medium immediately before the larvae were transferred and again after one day had lapsed. The control groups received an equivalent volume of distilled water at the same time in lieu of the antibiotics. Towards the end of the experiment it was necessary to feed the populations of 100 larvae more frequently than those containing 25 larvae to maintain a satisfactory concentration of food organisms. The results of the two experiments are shown in Table 2.

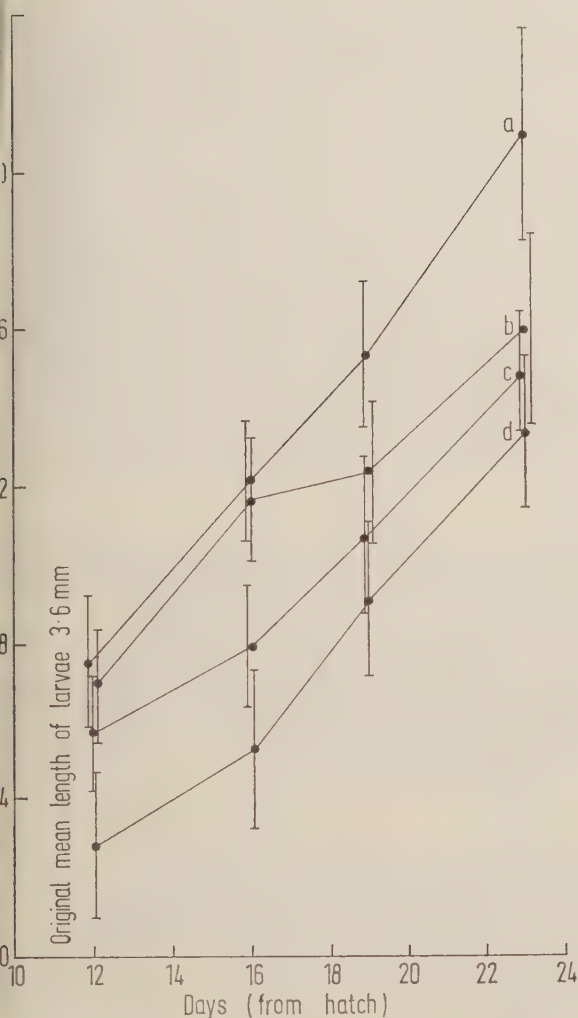
TABLE 2

The survival of Palaemon serratus larvae and the proportion which metamorphosed when cultured in the presence of antibiotics. Figures in parentheses refer to individual replicates

Expt	No. of larvae per litre	Age in days	Treatment		
			No antibiotics	Antibiotics	
Total percentage survival (larvae and post-larvae)					
A	100	21	73.5 (80, 67)	67.5 (65, 70)	
		24	72.0 (80, 64)	67.5 (65, 70)	
		28	69.5 (75, 64)	66.0 (63, 69)	
		30	59.0 (64, 54)	58.0 (56, 60)	
B	25	28	94.0 (96, 92)	90.0 (84, 96)	
		33	90.0 (96, 84)	90.0 (84, 96)	
		36	88.0 (92, 84)	86.0 (76, 96)	
Percentage of original population that were post-larvae					
A	100	21	3.5 (3, 4)	3.0 (4, 2)	
		24	30.0 (37, 23)	17.5 (15, 20)	
		28	60.5 (66, 55)	44.5 (39, 50)	
		30	59.0 (64, 54)	55.5 (52, 59)	
B	25	28	22.0 (12, 32)	10.0 (20, 0)	
		33	76.0 (72, 80)	70.0 (64, 76)	
		36	82.0 (80, 84)	84.0 (76, 92)	

Survival was similar in each trial in both control and experimental groups at the end of the culture period. The antibiotics did not significantly change the proportion of larvae that completed their development ($P > 0.05$), and when the sizes of early post-larvae were compared by 't' tests no significant differences were found ($P > 0.05$). The post-larvae were between 8.7 and 9.3 mm in length (mean 9.0 mm).

During the first five to seven days of metamorphosis in each trial an average of 28 per cent more larvae had metamorphosed at any given time in the cultures without antibiotics, although similar numbers metamorphosed eventually. It is possible that either the presence of antibiotics or their bactericidal action was responsible for slightly retarding the development of a proportion of the larvae. The



The growth of the larvae of *Palaemon serratus* that were subjected to different photoperiods. The 95 per cent confidence intervals are shown.

- a) Continuous light (20 lumens per square foot);
 b) 8 hours' dark, 16 hours' light;
 c) 16 hours' dark, 8 hours' light;
 d) continuous darkness.

ts showed however that the use of antibiotics was not necessary to obtain a good survival rate and a satisfactory proportion of post-larvae.

is series of six experiments showed that the larvae of *P. serratus* could be cultured—with good survivals—in natural sea water which was renewed at three-day intervals. If removal of precipitated matter was sufficient and more elaborate procedures were not found to be necessary.

EXPOSURE TO LIGHT

The larvae of *P. serratus* exhibit a positive phototaxis and congregate, under the influence of light, in a small proportion of the available volume of water. Under these conditions many larvae die, some due to the increased opportunity for cannibalism and others because of local pollution and oxygen shortage. The attraction to light was noted at all stages of the larval life. Reeve (1969a) attempted to induce an even distribution of larvae by culturing in darkness. He found that larvae subjected to this treatment survived less well than those reared in the light. The mean weekly difference in percentage survival was 12 per cent.

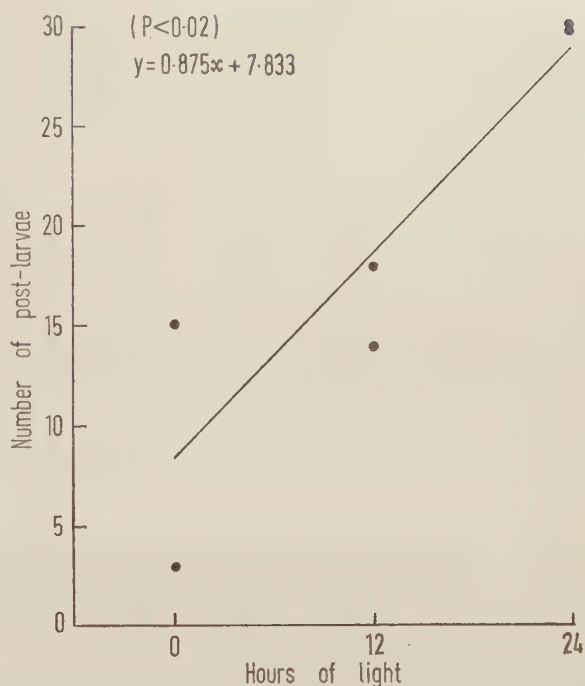


Fig. 2 The relationship between the number of *Palaemon serratus* larvae that had metamorphosed after 21 days of culture and the daily period for which they had been illuminated.

In order to examine more closely the effect of photoperiod on the development of larvae, three replicate populations were cultured in (a) continuous light (20 lumens per square foot), (b) daily periods of 16 hours' light, 8 hours' darkness, (c) daily periods of 8 hours' light, 16 hours' darkness, and (d) continuous darkness. The larvae were measured when they were 12, 16, 19 and 23 days old, and their mean lengths are shown plotted against age in Figure 1. Those larvae cultured in darkness were consistently smaller ($P < 0.05$) than those grown in continuous light and, after 16 days, those grown in 16 hours' darkness, 8 hours' light were also smaller ($P < 0.05$) than those cultured in continuous light. The duration of the larval phase was also affected by the photoperiod; larvae cultured in the light completed their development sooner than those cultured in darkness, although the results were numerically marred by post-larvae which preyed upon the remaining larvae. Another experiment was made to check this in which replicate populations of 50 larvae were cultured in darkness, continuous light and 12 hours' light, 12 hours' dark. The results in Figure 2 show a positive correlation ($P < 0.02$) between the number of larvae which had metamorphosed after 21 days and the hours of light received each day during the culture period. During the same period there was no statistically significant relationship between hours of illumination and mortalities ($P > 0.05$).

The experiments showed that growth and metamorphosis were improved when larvae were cultured in continuous light, compared with those subjected to long periods of darkness.

FOOD

The live nauplii of *Artemia salina* are by far the most successful food yet found for prawn larvae. Prepared foods that have been tried—chopped ox liver and chopped mussel meat—were not satisfactory, since they either decomposed in sea water or were unacceptable to the larvae (Reeve 1969a).

In the following experiments the food value of *Artemia* from different sources was compared and the effects of a supplement of algae to cultures of larvae and *Artemia* were observed. Another live food—small worms of the genus *Lumbricillus*—was also tested but found to be unsuitable.

Source of Artemia: The survival of crustacean larvae fed with live *Artemia* nauplii has been discussed in some detail (Reeve 1969*a*, Bookhout and Costlow 1970, Wickins 1970). Nauplii hatching from eggs collected from salt pans near San Francisco are known to be a good food for prawn larvae, whereas some batches from the Great Salt Lake, Utah only become satisfactory after they have consumed some algae (Wickins 1970).

During the present study larvae were fed with *Artemia*

from three different regions in North America: (i) Saskatchewan, Canada, (ii) San Francisco, USA and (iii) Utah USA. The Utah eggs were obtained from two suppliers, one in Britain and the other in Germany. Altogether the sponges of eight broods of larvae to the foods were tested. The larvae were cultured at densities between 20 and 100 per litre for an average of 30 days. The mean numbers that survived and the proportion which metamorphosed are shown in Table 3. Heavy mortalities occurred among larvae fed with Utah *Artemia*, but good survival rates (64 per cent after 30 days) were obtained when *Artemia* from San Francisco and Saskatchewan were used. Larvae fed with batches from Utah were not adversely affected until the last larval stages and during metamorphosis. This is shown in Table 4 where the mean total survival of larvae immediately before and just after metamorphosis is tabulated for each diet.

TABLE 3
The survival of Palaemon serratus larvae fed with the nauplii of Artemia salina from Saskatchewan (Canada), San Francisco (USA) and Utah (USA). The Utah variety came from agents in both Britain and Germany. Eight broods of larvae were tested in two and three replicate populations of 20–100 larvae per litre. The mean duration of the experiments was 30 days

	Source of <i>Artemia salina</i> eggs			
	Saskatchewan	San Francisco	Utah	
			Germany	Britain
Number of trials	4	7	4	6
Total percentage survival (larvae and post-larvae)	61.5	68.5	11.6	22.0
Percentage of original population that were post-larvae	53.0	57.5	7.6*	14.5*

*The post-larvae were deformed.

TABLE 4
The percentage of Palaemon serratus larvae that survived metamorphosis after they were fed with four varieties of Artemia salina nauplii

	Source of <i>Artemia salina</i> eggs			
	Saskatchewan	San Francisco	Utah	
			Germany	Britain
Number of trials	2	6	2	6
Percentage survival: Before metamorphosis (mean age of cultures 17.2 days)	76.0	76.5	75.0	75.0
After metamorphosis (mean age of cultures 24.5 days)	68.0	69.5	19.0	26.1

Measurements of length made during one of the trials after 17 days of culture showed that larvae grew at the same rate, irrespective of diet. The means, which ranged from 7.1 to 7.8 mm (mean 7.5 mm), did not differ significantly ($P > 0.05$). The mortalities that occurred during the last week of culture among larvae fed Utah *Artemia* did not occur among those fed with the Saskatchewan or San Francisco varieties. On these diets 55 per cent of the larvae developed successfully to the post-larval stages.

Supplement of algae: The experiments just described showed that *P. serratus* larvae will successfully develop to the post-larval stages solely on a diet of San Francisco *Artemia* nauplii. In five experiments, which were made with four broods of larvae, this diet was supplemented by a quantity of the alga *Isochrysis galbana*. The quantities of algae added were sufficient to give initial concentrations of between 50 and 200 cells per μ l and each of the experimental cultures received this dose at one-day intervals. Both culture medium

Artemia were renewed at three-day intervals. The mean results of the five experiments are given in Table 5. The supplement of algae did not significantly improve the overall survival or the proportion of post-larvae that developed (0.05). In three of the trials early post-larvae were measured but they did not differ significantly in size according to the treatment they had received ($P > 0.05$). Their mean lengths were between 8.8 and 9.2 mm with a mean of 8.9 mm. However, metamorphosis was earlier among broods that received the supplement of algae. The mean of the age differences between the two groups, calculated when 30 per cent of the animals were post-larvae, was four days; by the time 50 per cent had metamorphosed the mean difference was reduced to one day. During the first week of metamorphosis an average of 35 per cent more post-larvae had developed in the presence of algae compared with the control groups.

In these tests larvae completed their development more quickly when cultured in the presence of the alga *Isochrysis* than when they were otherwise unaffected.

Lumbricillus as a food: The cannibalistic tendencies of the larvae and their ability to feed on particles at least as large as themselves indicated that they might be able to take such small worms as the marine oligochaete *Lumbricillus* (Enchy-

traeidae). This species was found locally amongst rotting seaweed and was cultured at Conway by my colleague, Mr T. W. Beard. It was of interest as a possible alternative food for larvae because of the high cost of live *Artemia*. Its food value was determined by comparison with partially grown *Artemia* (1.3–3.8 mm, mean length 2.2 mm). In the test a small number of worms, usually between 20 and 40 (4–8 mm long), were placed with 10 twelve-day-old larvae in two replicate cultures. The larvae had previously been fed with Saskatchewan *Artemia*. Control cultures were fed with the partially-grown *Artemia*. After 11 days the mean length of larvae fed with *Artemia* was 8.5 mm, which was significantly larger ($P < 0.05$) than those fed with worms (6.4 mm). After a further 7 days of culture only 25 per cent of the experimental larvae survived, one of these being a post-larva, but 75 per cent of the control populations had reached the post-larval stage.

During the experiment some larvae were seen carrying worms, presumably in an attempt to eat them, but there was also evidence of cannibalism amongst the larvae, which suggested that the worms were not particularly attractive as food. They quickly formed clumps at the bottom of the beakers in which many larvae became smothered; the *Artemia*, on the other hand, swam throughout the available volume of water and were always near to the larvae.

TABLE 5

The survival and age at metamorphosis of Palaemon serratus larvae cultured with Artemia salina nauplii in the presence of the alga Isochrysis galbana. The mean results of five experiments (mean duration 32 days) made with two to four replicate populations of 10, 25, 25, 25 and 100 larvae per litre are presented. Figures in parentheses represent the range of the results.

	Food			
	<i>A. salina</i> nauplii (San Francisco variety)		<i>A. salina</i> nauplii (San Francisco variety) with <i>Isochrysis</i>	
	Age of culture (days)			
	25	32	25	32
Total percentage survival (larvae and post-larvae)	81.5 (72-94)	75.4 (65-88)	85.8 (74-96)	77.9 (65.5-90)
Percentage of original population that were post-larvae	22.9 (5-60)	65.1 (30-84)	35.4 (20-46)	73.0 (65-80)
Age (days) when 30% were post-larvae	29		25	

TEMPERATURE

The period of egg incubation in wild populations of *P. serratus* can be related to the temperature of the surrounding water (Cole 1958). Reeve (1969a) and Phillips (1971) were able to show this relationship with *P. serratus* females that had spawned in the laboratory. Reeve found that the mean time of egg carriage at 20°C was 28 days and at 15°C was 35 days. The effects of temperature during incubation and culture of larvae was tested at three levels in a 3 × 3 factorial experiment. Small prawns (78–85 mm) which carried eggs at an early stage of development were selected from a catch made in Holyhead harbour in July 1968. The eggs were a uniform green colour and had not developed eyespots. The prawns were kept at three temperatures (15, 18 and 21°C),

and the first brood of larvae to hatch from each group was split into populations of 50 larvae which were then cultured in duplicate at the same three temperatures. The total numbers of larvae completing their development in each treatment were:

Egg incubation temperature (°C)	Larval rearing temperature (°C)			Total number of post-larvae
	15	18	20	
15	8	72	66	146
18	8	74	84	166
20	53	80	88	221
Total post-larvae	69	226	238	533

The results were subjected to an analysis of variance:

Source of variation	Sums of squares	Degrees of freedom	Mean square	Variance ratio
Larval rearing temperature	5928.2	2	2964.1	18.1*
Incubation temperature	1005.6	2	502.8	3.1
Residual	653.8	4	163.4	
Total	7587.6	8		

* $P < 0.05$.

The effect of temperature on the development of larvae was more pronounced during the free-swimming stages than during incubation ($P < 0.05$) and more larvae metamorphosed at 18–20°C than at 15°C. Eggs incubated at 15°C gave rise to fewer post-larvae than those held at 20°C although the trend was not significant ($P > 0.05$). Wickins (1972) mentioned that the viability of *Pandalus platyceros* larvae might be affected by temperatures experienced during incubation, and Price and Chew (1969) reported that eggs collected from ovigerous *P. platyceros* which were incubated at 11°C hatched later, but produced better larvae, than eggs held at 13 or 15°C.

In culture programmes it is often necessary to adjust the timing of hatches of larvae—and also the rate of development—so that the required number of seed post-larvae may be obtained at the most convenient time. The rate of embryonic development may be conveniently retarded by low temperatures but it is possible that this treatment could affect the subsequent viability of the larvae. In this experiment the temperature at which larvae were reared had a more pronounced effect than the incubation temperature.

INCUBATION OF EGGS *in vitro*

Some female decapod crustacea, particularly crabs and lobsters, are known to remove their eggs from the pleopods if disturbed or when placed in a new environment (Provenzano 1967). This activity has not been observed with *P. serratus* at Conway but on occasions captive females died or were accidentally killed while carrying live eggs. Two attempts were made to hatch these eggs. In the following trials eggs that were judged to have passed through 50 and 75 per cent of the incubation period were removed from two laboratory-reared females and cultured at 20°C *in vitro*. Normally incubation takes 28 days at 20°C (Reeve 1969a).

The eggs were carefully removed with a fine paint brush and forceps and washed in clean sea water. The hatching vessel in which they were placed is shown in Figure 3. The water was renewed every two days, at which time antibiotics were added to reduce the growth of micro-organisms. Gentle aeration maintained a slow flow of water through the egg masses. The larvae that hatched were then cultured until they metamorphosed. The results were:

	Number of eggs removed (approximately)	Incubation time (days)	Number of larvae	Number of post-larvae
Female 1	200–300	14	147	36
Female 2	1 200	7	650	226

The technique, although simple, gave reasonable results and produced viable larvae. There is therefore no reason

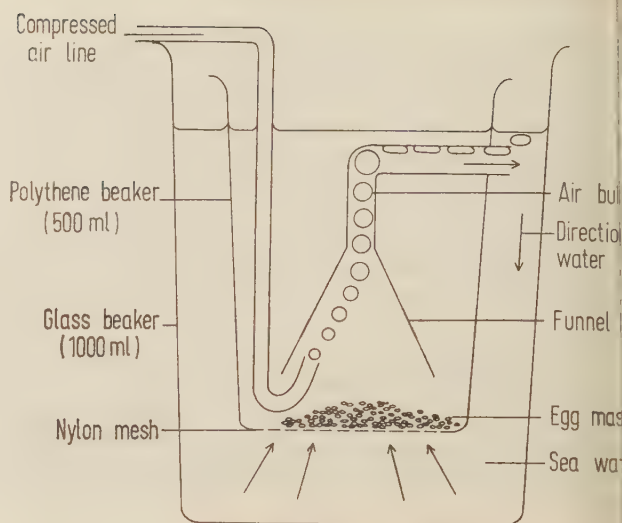


Fig. 3 The apparatus used for the incubation of *Palaemon serratus* eggs *in vitro*. Arrows indicate the direction of water movement.

why larger numbers of eggs cannot be artificially incubated and hatched, should the need arise. Indeed, Phillips (1967) described attempts to hatch 712 000 *P. serratus* eggs in conical incubators, but unfortunately an infection reduced the proportion which hatched to 9.4 per cent.

LARGE-SCALE LARVAL REARING

Throughout 1967 and 1968 larger numbers of larvae were cultured in 75 litre vessels. One method, in which the cultures were provided with a flow of natural sea water, was used in a trial made in April 1967 and resulted in an overall survival of 36.1 per cent to the post-larval stage (Forsyth 1970a). This method was successful in 1967 during March, April, June, July and August, but in May 1968 six similar cultures collapsed within a period of three weeks. The collapse coincided with a bloom of the colonial alga *Phaeocystis pouchetti* (Hariot) Lagerh in the Conway Estuary; this alga develops regularly in May and June each year and is known to suppress the growth of oyster larvae (Walne 1970). The presence of *Phaeocystis* was assumed to have caused the deaths of the prawn larvae and shortly afterwards an experiment was made to see if the quality of the sea water could be improved by filtration. Four populations of 100 four-day old larvae, all from one brood, were reared in polythene buckets containing 6 litres of sea water. Two buckets were provided with a flow of natural sea water to simulate conditions in the cultures that had collapsed and two more were held in standing, filtered, sea water. The cultures were attended daily and washed out twice each week when the filtered water was renewed. After 12 days few larvae (13 per cent) remained in the cultures that received natural sea water, while over 80 per cent were surviving in the filtered water. The results, presented in Table 6, showed that, during the bloom of *Phaeocystis*, larvae in filtered water were more likely to survive than those in a flow of natural sea water. Accordingly, in June and July of 1968 releases of larvae were reared in filtered sea water. In Table 7 the results of mass cultures made in 1967 and 1968 are presented. Data are included on the initial stocking densities of larvae and the number of post-larvae in each vessel. Double asterisks denote that the numbers of post-larvae recorded were not the total yield, but were the numbers removed at the first harvest; larvae that remained after this were often combined with those remaining from other vessels. The cultures were

TABLE 6

The survival of Palaemon serratus larvae cultured in natural sea water in June 1968 during a bloom of the colonial alga Phaeocystis pouchetti. Two replicate populations of 100 larvae were used for each treatment

	Treatment			
	Flowing natural sea water		Standing filtered sea water	
	Replicates			
	1	2	1	2
Total percentage survival after 12 days of culture	7	20	87	80
Total percentage survival after 26 days of culture (larvae and post-larvae)	5	11	64	59
Percentage of original population that were post-larvae after 26 days of culture	4	6	54	56

TABLE 7

The numbers of Palaemon serratus larvae reared and the numbers of post-larvae obtained from mass cultures in 60 litres of flowing, natural sea water of 65 litres of standing, filtered sea water

	Initial Number of larvae in each vessel	Number of larvae per litre	Number of post-larvae in each vessel	Percentage of post-larvae	Age of culture when harvested (days)	Notes
Flowing, natural sea water	7 670	128	747	10	34	Flowing, natural sea water
	7 800	130	1 525	20	18	"
	9 000	150	2 400	27	19	"
	6 000	100	1 650	27	22	"
	11 300	188	2 000	18	22	"
	11 300	188	2 700	15	22	"
	24 000†	120	2 400	10	32	"
	3 000	50	1 725	58	21	"
Standing, filtered sea water	4 550	76	0*	0	3	"
	22 000	366	1 350	6	25	"
	22 000	366	1 050	5	24	Standing, filtered sea water
	6 400	106	0*	0	8	"
	6 400	106	0*	0	8	Flowing, natural sea water
Six cultures collapsed (see text)						
	5 400	83	2 450	45	25	Standing, filtered sea water
	7 680	118	2 900**	38	26	"
	10 400	160	3 150**	30	27	"
	9 600	148	1 750**	18	27	"
	15 600	240	4 300**	27	30	"
	13 100	202	3 650**	28	29	"
	13 350	205	4 400**	33	31	"
	13 350	205	1 400**	10	34	"
	12 100	186	2 255**	19	31	"
	11 200	172	3 000**	27	35	"
	3 100	48	1 300**	42	29	"
	3 400	53	2 150**	62	29	"
	2 400	37	0*	0	25	"
	2 200	34	1 650**	75	28	"

* Reared in a 200 litre vessel.

† Sudden total mortality, causes unknown.

** Not total yield; but numbers removed at first harvest (see text).

larvae were reared in either 60 litres of flowing (natural) sea water or in 65 litres of standing filtered water.

The average concentration of larvae was 158 per litre (range 34 to 366 per litre) and the average proportion which passed through metamorphosis was 27.3 per cent. Altogether 50 000 post-larvae were reared. The mean duration of larval life was 26.6 days and although it appeared that

the larvae cultured in flowing sea water developed more rapidly, a 't' test showed that the mean lifespans were not significantly different ($P > 0.05$).

The relation between the initial density and yield is depicted in Figure 4. The yield of post-larvae was expressed as a percentage of the original population and plotted on a logarithmic scale. In this way the relationship between the

transformed yield and the initial density are described by the regression equations:

$$Y = 149.50 - 56.94 \log_{10}X$$

and $\log_{10}X = 2.48 - 0.01 Y,$

where X is the initial number of larvae per litre and Y is the percentage of post-larvae obtained. (Cultures that collapsed were not included in the graph but are declared in Table 7). There was a decreasing proportional yield with increasing numbers of larvae per litre, and the regression was highly significant ($P < 0.001$).

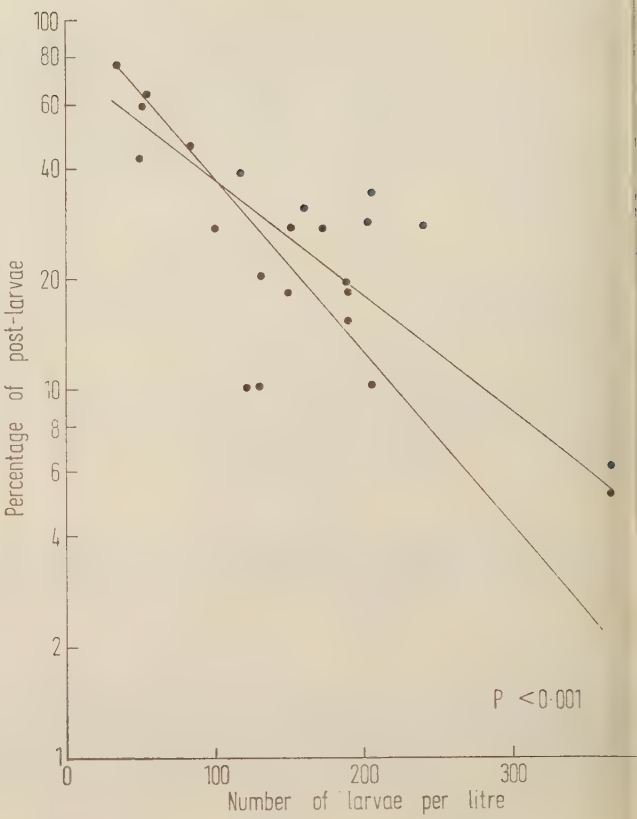


Fig. 4 The relationship between the initial number of *Palaemon serratus* larvae and the proportion that metamorphosed during mass culture. The calculated regression lines are drawn.

Experimental Results: Post-Larvae

GENERAL

Forstner (1963) cultured the larvae of *Palaemon elegans* and found that larvae which moulted 6 times before metamorphosing were generally smaller than those which moulted 7 or 8 times. In the present study it was noticed that the first larvae to metamorphose in a population were usually smaller than those metamorphosing later. For example, post-larvae from the control populations of four other experiments were measured as soon as they had completed metamorphosis and a 't' test was used to test the difference between the mean lengths of the first 50 per cent of populations to metamorphose and the remainder. The results were:

Experiment number	Mean length of first 50% of post-larvae to metamorphose (mm)	Mean length of second 50% of post-larvae to metamorphose (mm)	Probability
1	7.9	8.7	$P < 0.05$
2	8.0	8.4	$P < 0.10 > 0.05$
3	7.8	8.6	$P < 0.05$
4	7.4	8.0	$P < 0.05$

In three of the four experiments the first post-larvae to develop were significantly smaller than later post-larvae ($P < 0.05$), but since these were from populations no information was available on the numbers of moults achieved by each group of prawns.

Following metamorphosis post-larvae spend a decreasing proportion of their time swimming and begin to adopt the resting habits typical of the adults. At this time they moult every 3 to 6 days and when suitable food is available they grow from about 5 to 15 mg in two weeks. In the present work the change of diet from the live *Artemia* nauplii they received as larvae to prepared foods such as pieces of *tilus* mantle tissue was made gradually in order to maintain good survivals (Forster 1970a).

FREQUENCY OF FEEDING

An experiment was made in which food—pieces of *Mytilus* mantle tissue—was made available to rapidly growing post-larvae (mean weight 8.2 mg) for a limited period only each day. In the experiment three groups of 10 newly-metamorphosed post-larvae were cultured in separate containers for 30 days. During the first 10 days food was given to prawns in group 1 for 16 hours per day (1700–0900 hours), in group 2 for 2 hours each day (0900–1000 hours and 1700–1800 hours) and in group 3 for 1 hour each day (0900–1000 hours). The prawns, cultured in 2 litre polystyrene vessels measuring 13 × 13 × 17 cm deep, were transferred to fresh water twice per week and weighed every 10 days.

The average growth rates of the three groups are shown in Figure 5, where their mean weights are plotted on a logarithmic scale against time. The number of survivors in each of the three groups after 10 days were 8, 10 and 7 prawns respectively. At this time the mean weight of those fed for 16 hours each day had decreased from 8.4 to 7.8 mg and was significantly smaller ($P < 0.05$) than the mean of those fed

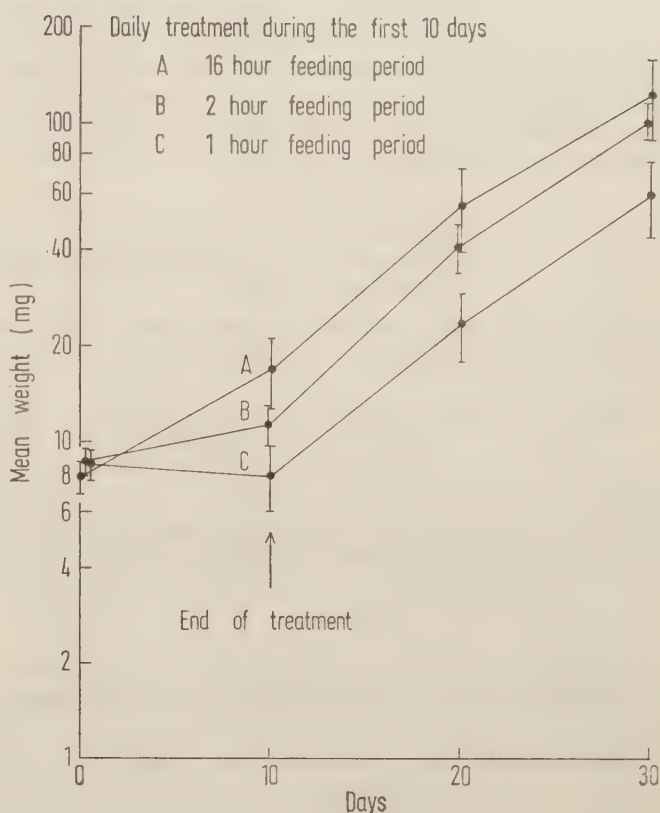


Fig. 5 The growth of *Palaemon serratus* post-larvae that were restricted to discrete daily feeding periods for 10 days, and then fed for 16 hours daily for a further 20 days. Each point represents the mean weight of seven to ten individuals, and the 95 per cent confidence intervals are shown.

for 16 hours per day (16.8 mg). The mean weight of prawns fed for 2 hours per day (11.2 mg) was not significantly different from that of either of the other groups. The prawns were cultured for a further 20 days, during which time each group was fed for 16 hours per day after the manner of group 1.

The slopes drawn in Figure 5 showed that when food was again made plentiful the prawns recovered very quickly and each group grew at a similar rate (3–5 mg per day). Prawns that were fed initially for 1 hour each day did not, however, catch up with the other groups and at the end of the experiment they were still significantly smaller ($P < 0.05$). Their mean weight was 60.4 mg, compared with weights of 103.7 and 125 mg for the animals which had been fed for 2 and 16 hours respectively, between which there was no significant difference in size. The prawns showed that they were able to withstand considerable stress at an early age and that their powers of recovery after starvation were good.

CANNIBALISM

The utilization of shelves by populations of prawns: Forster (1970a) records cannibalism as the greatest single cause of mortality in captive prawns, and describes how it was reduced by increasing the effective floor area of a tank. The increase in area was achieved by providing a stack of black PVC sheets spaced about 5 cm apart and mounted horizon-

tally on a wooden frame. The extent to which prawns actually used such extra surfaces was observed when a stack of two sheets was placed in a 10 litre transparent aquarium. Groups of 30 to 50 prawns (mean size *c.* 40 mm) were observed over a period of two months and the numbers resting on each of the available surfaces were recorded separately. In Table 8 the means of all the observations are presented. Each entry represents the preference of prawns for a particular surface and is expressed as the mean percentage of the total population on the surface at each observa-

tion. The most interesting observation was the ability of inclination of the prawns to rest upside down on the undersides of the shelves. The greater proportion of prawns that rested on the floor and lower surface of the shelves, as opposed to the upper, was judged to be a movement away from light. If shelves were to be used as a means of increasing the surface area available for prawns to settle on and thus to encourage their distribution throughout the available volume of water, then the best effect would probably be obtained if the tanks were shaded.

TABLE 8
The preference of juvenile Palaemon serratus for particular resting places in a tank containing two shelves

Description of resting place		Mean percentage of the population in each position	Standard error of the mean
Top shelf	{ upper surface	6.28	0.8013
	{ lower surface	14.06	1.2897
	{ total	20.35	1.5841
Second shelf	{ upper surface	14.04	1.0606
	{ lower surface	20.61	1.6664
	{ total	34.65	1.2311
Tank floor		36.03	1.5458
Prawns swimming freely		9.06	1.3283

LARGE-SCALE EXPERIMENTS

Population size, growth and survival: An experiment was made in the summer of 1968 to test the effect of population size on the growth and survival of young prawns. In the trial, duplicate populations of 4 000, 2 000, 1 000, 500 and 250 hatchery-reared post-larvae were cultured outdoors for 91 days from July to October. They were kept in wooden tanks (1.2 × 1.2 × 0.3 m deep) and were shielded from direct sunlight by corrugated sheets of opaque plastic (Plate 2). Two-thirds of the water in the tanks was changed once per week and the whole completely renewed every four weeks when the tanks were thoroughly cleaned. Each day the prawns were given freshly-cut halves of *Carcinus* and *Mytilus* in such quantities that a little food remained the next day. The temperature range was 9–23°C (mean 14.7°C) with a maximum diurnal variation of 7°C.

On average the prawns increased from 11 to 293 mg during the trial, but there was no correlation between the initial population density and the growth of the prawns. The survival ranged from 15 per cent in the tank initially containing 4 000 prawns to 73 per cent with 250 prawns per tank. The relationship between the initial population size and the survival is shown in Figure 6.

In terms of production per unit area the tanks which produced the greatest weight of prawns, 172 g (i.e. 119 g per m²), were initially stocked with 2 000 prawns but the greatest percentage increase in biomass (1 980 per cent) occurred in the tanks initially containing 500 prawns (Table 9). The results of this trial show that the greatest yield of prawns obtainable from 44 g of seed stock (4 000 prawns) would be from nearly 9 (i.e. 8.8) tanks stocked with 500 prawns each. This would produce a total of 915 g of prawns. The weight of prawns produced for each gramme of prawns stocked in the tanks (1.44 m² floor area) per m² was:

Initial number of prawns per tank	Initial biomass per tank (g)	No. of tanks needed	Weight of prawns produced (g) per g of prawns stocked per m ² of tank floor
4 000	44	44/44 = 1	2.50
2 000	24	44/24 = 1.83	4.98
1 000	12	44/12 = 3.67	6.80
500	5	44/ 5 = 8.8	14.45
250	2.5	44/ 2.5 = 17.6	13.60

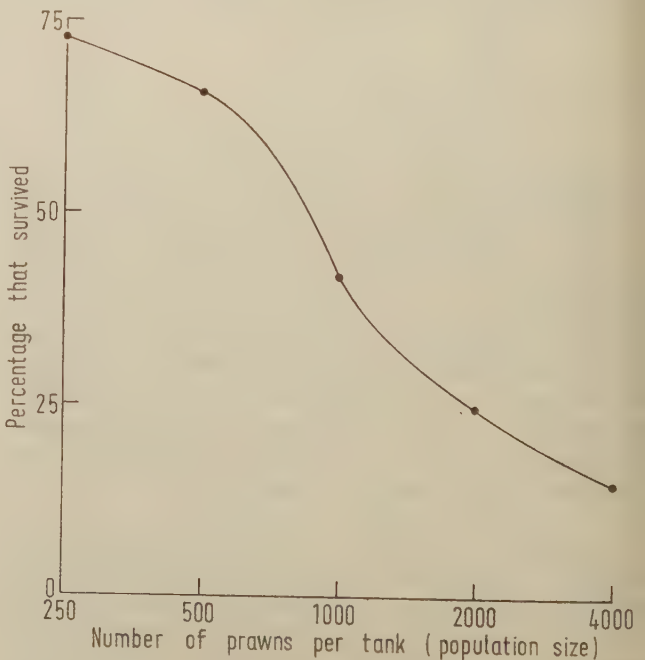


Fig. 6 The relationship between initial population size and the survival of *Palaemon serratus* reared in tanks 1.44m² in area.

TABLE 9

The survival and growth of *Palaemon serratus* juveniles (initial mean weight 11 mg) cultured outdoors in tanks for 91 days in 10 tanks at each initial density

Initial number of prawns per tank	Final number of prawns	Percentage lost per week	Initial biomass (g)	Final biomass (g)	Percentage increase in biomass	Yield (g/ms)
4 000	586 644	6.55	44	158	259	110
2 000	548 461	5.77	24	172	617	119
1 000	492 344	4.46	12	117	875	81
500	366 294	2.62	5	104	1 980	72
250	187 177	2.08	2.5	49	1 860	27

It does not necessarily follow that this result can be extrapolated to other sizes of tank, since it has been suggested that the behaviour of prawns relating to cannibalism is affected by tank dimensions (Forster 1970a). Measurements of total length were made on random samples of 100 prawns from each group at the start and end of the trial. The mean results and the coefficient of variation

$$\left(\frac{\text{standard deviation}}{\text{mean}} \times 100 \right)$$

for the samples are given in Table 10. The coefficient of variation showed that the relative range of sizes probably did not change over the three-month period. A decrease could be expected if, for example, small prawns were being selectively cannibalized by larger ones, but there was no evidence of this.

Maintenance of stocks of prawns during winter: At the end of the summer growth experiment described above, the remaining 4 099 prawns were taken indoors and over-wintered in four 400 litre tanks (122 × 61 × 61 cm deep). These were provided with a flow (c. 60 litres per hour) of sea water at ± 2°C recirculated from a 12 000 litre reservoir. Each tank contained three horizontal sheets of plastic 5 mm mesh measuring 70 × 45 cm placed 10 cm apart, which provided additional surfaces for the prawns to rest on. Fresh *Mytilus*

was provided daily as food, and detritus which accumulated in the tanks was removed by siphoning. Each week approximately 25 per cent of the reservoir volume was drained off and clean sea water added.

In May 1969, 7 months later, 1 147 prawns remained (517 females and 630 males), a survival of 28 per cent. Their mean weight had increased from 0.3 to 1.2 g (see Figure 9). The mean loss of prawns per week (2.4 per cent) compares favourably with the rate of loss from the 500 and 250 populations of the summer experiment, which were 2.6 and 2.1 per cent per week respectively.

The prawns ranged in size from 30 to 78 mm, and the coefficient of variation of the whole population (14.3) was little different from the mean (17.8) of the sample coefficients determined at the end of the summer. It is not known if the range of sizes was influenced by the environment or was inherent in the genetic constitution of the animals. The same prawns were used in the next experiment which commenced in May 1969.

Population size, sex, growth and survival: This trial was made in the same tanks and general conditions as the one already described which took place in July 1968. The differences

TABLE 10

The relative range of sizes in replicate populations of *Palaemon serratus* after 91 days of culture, as shown by the coefficient of variation $\left(\frac{\text{standard deviation}}{\text{mean}} \times 100 \right)$

Initial number of prawns per tank	Mean initial length (mm)	Coefficient of variation	Mean final length (mm)	Coefficient of variation
4 000	23.3 23.3	19.80 20.85	28.6 29.4	20.23 18.75
2 000	25.3 24.5	17.65 19.44	33.1 31.5	15.95 18.06
1 000	24.9 22.6	17.89 22.65	31.0 29.3	15.84 19.08
500	25.1 24.6	16.27 24.05	30.9 31.5	15.99 21.31
250	23.6 23.8	18.52 20.32	30.8 28.7	15.35 18.06

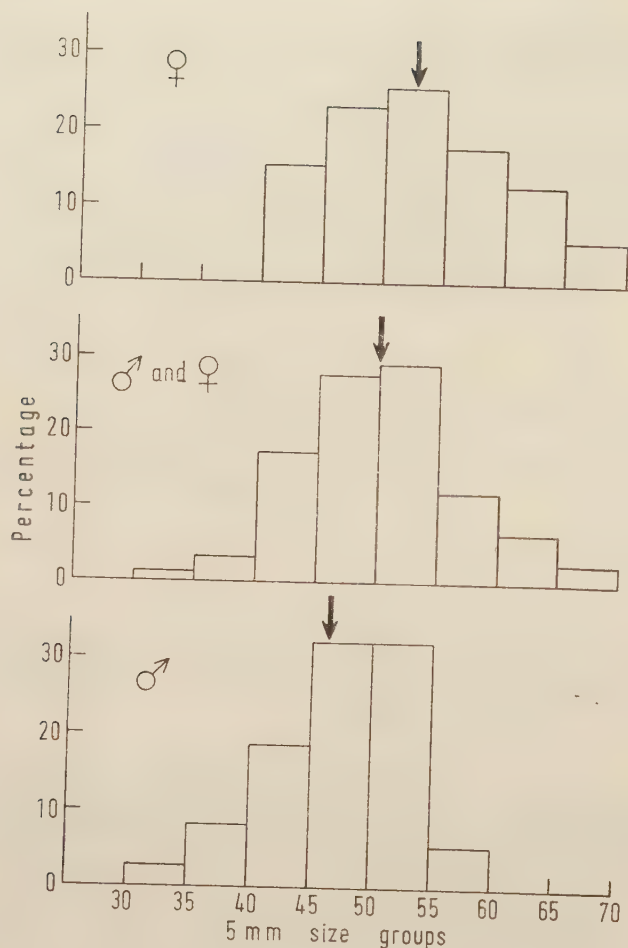


Fig. 7 The initial distribution of sizes in populations of *Palaemon serratus* reared in tanks. The mean lengths are shown by arrows.

were that the prawns were larger, the population sizes were smaller, and the sex ratio of each group was adjusted. Three sex ratios were used: 100 per cent males; 50 per cent males, 50 per cent females; and 100 per cent females; each was tested at three densities, 36, 75 and 150 prawns per tank. The prawns were divided into 5 mm length groups and distributed evenly so that each population had the same structure (Figure 7); the females (mean weight 1.5 g) were, however, slightly larger than the males (mean weight 1.0 g). The experiment lasted 130 days. The water temperature fluctuated between 7 and 31°C (mean 17°C) and the maximum diurnal variation was 11°C. At the end of the experiment the prawns were sexed and weighed. The numbers remaining were:

Initial population	Initial number of prawns per tank		
	150	75	36
Males	90	55	7*
50% males and 50% females	83 (40 males) (43 females)	32* (21 males) (11 females)	26 (11 males) (15 females)
Females	61	50	30

The figures marked with an asterisk are believed to be freak results and prevented any meaningful statistical treatment being applied to the figures.

It was possible that mortality was slightly greater amongst females than males (chi-squared test $P < 0.1 > 0.05$) at the

highest density tested (150 prawns); if so, it might have been due to the larger initial size of the females (1.5 g) compared with males (1.0 g), rather than sex. In the mixed populations there was no evidence to show that the survival rates of either sex were different. Forster (1970a) confirmed that cannibalism was not restricted by sex in populations of *serratus*. When the females were considered alone the percentage mortality increased significantly ($P < 0.001$) as density increased:

Population density	Percentage mortality of females
150	59
75	33
36	17

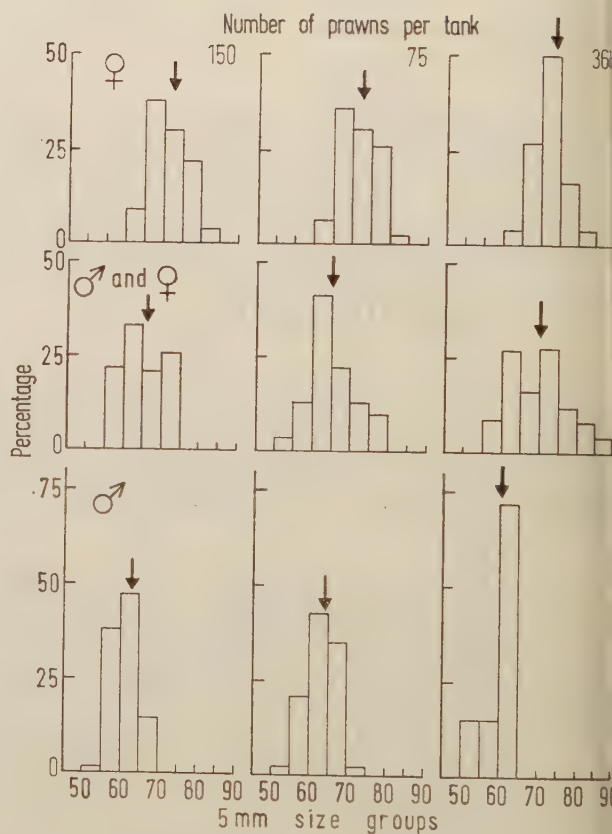


Fig. 8 The final distribution of sizes in populations of *Palaemon serratus* reared in tanks. The mean lengths of the populations are shown by arrows.

In Figure 8 the final size distributions of the populations are compared. The results were expressed as the percentage of survivors in each 5 mm size group because of the different population sizes. There was no noticeable effect of population size on the final mean lengths of the prawns, although the percentage increase in mean weight was greater in the smaller populations and among the female prawns:

Initial population	Initial number of prawns per tank		
	150	75	36
Males	112	126	139*
Males and females	125	117*	146
Females	127	140	147

* Freak results.

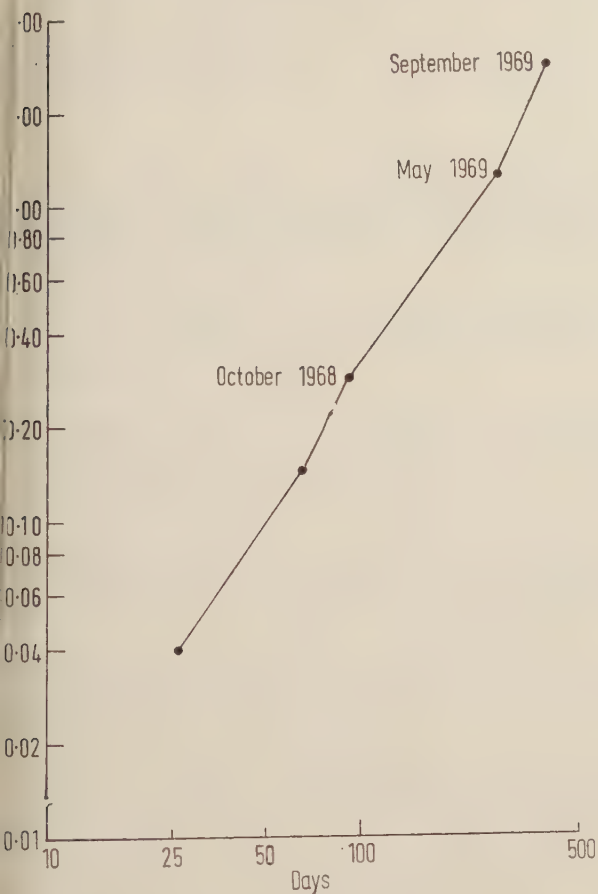


Fig. 9 The growth of *Palaemon serratus*.

However, individual chi-squared tests made on the data of the bottom row and the left-hand column (thus omitting the tank results) were not significant ($P > 0.05$) on these points.

When the experiment ended the prawns were just 15 months old and had more than doubled their weight in the previous four months. Although they made good eating at the time they were too small to have commanded reasonable market prices. The mean weight of the females was 3.4 g and of males 2.3 g; 7.6 per cent of the females (but none of the males) were over 80 mm in length and were estimated to weigh nearly 4 g. The growth of this batch of prawns from a mean weight of 2.8 g between May and September 1969 is shown in Figure 9. The production per unit area in the tanks was low (c. 150 g per m²) even at the highest densities, where the losses per week were between 2.1 and 3.2 per cent. There is some evidence (Forster 1970a) that survival and hence production may be a function of tank size or shape, and is not necessarily restricted by the number of prawns per unit area of tank floor.

One of the females in the mixed populations were seen in an ovigerous condition during the trial, and the reason for this is not known. On other occasions (see below) laboratory-reared prawns have matured and spawned within months of hatching.

PRAWNS REARED THROUGH SEVERAL GENERATIONS IN CAPTIVITY

Beginning in 1967 stocks of prawns were maintained continuously in the laboratory. One of these stocks was reared through two filial generations in isolation. The F₂ progeny (out of 40 prawns) were mixed, shortly after metamorphosis,

with 60 F₁ post-larvae of equivalent age and the resultant stock reared through a further two filial generations in captivity. By the summer of 1970 the only survivors were males, which were subsequently returned to the laboratory stocks. Throughout this time the prawns had received fresh *Mytilus* tissue as food.

The generation times (from hatching to hatching) in the consecutive generations were 10, 7 and 8 months. The mean times taken from hatching to metamorphosis were 30, 24, 19 and 31 days, but the exact incubation times (judged to be between 4 and 6 weeks) were unknown since the prawns were only inspected intermittently. The females released small numbers of larvae (< 1 000), which was probably because of their small size (Reeve 1969a) but may also have been affected by the fact that they were spawning for the first time. The fecundity of wild females of equivalent size spawning for the first time is not known.

In the laboratory prawns were seen to mature before reaching a commercial size. It is also known that their gonads can ripen up to three times in one year (Forster 1970a). Under these conditions the growth effort is not totally directed towards an increase in the edible flesh of the animal. This could be uneconomical for the culturist, because a proportion of the food supplied would be utilized in the development of reproductive tissue.

Summary

The prawn *Palaemon serratus* Pennant was cultured through four generations in captivity. The mean generation time was eight months.

Larvae grew equally well for most of the year in either natural or filtered sea water which was renewed at three-day intervals.

The addition of a mixture of antibiotics to cultures slightly retarded the development of a proportion of the larvae, which were otherwise unaffected.

The growth and development of larvae was inhibited by long periods of darkness; best results were obtained from cultures that were continuously illuminated.

The newly-hatched nauplii of *Artemia salina* L. from Saskatchewan and San Francisco were good food for larvae but those from Utah were not.

Larvae completed their development more rapidly when cultured with *Artemia* in the presence of the alga *Isochrysis galbana*.

Incubation of the eggs at low temperatures (15–18°C) resulted in larvae that did not survive well when cultured at low temperatures (15°C).

- 8 Viable larvae were obtained from eggs incubated *in vitro*.
- 9 During the mass culture of larvae, 50 000 post-larvae were reared with a mean survival of 27 per cent.
- 10 Post-larvae that were restricted to a one-hour feeding period per day for 10 days decreased in weight but rapidly recovered and grew well when food was made available for 16 hours per day.
- 11 The effect of population size on the growth of young (11 mg) prawns was studied. The most efficient production in terms of the weight of prawns produced per g of prawns stocked per square metre of tank floor area was obtained in tanks containing 350 prawns per m². These yielded, after three months, 14.45 g per g of prawns stocked per m².
- 12 Prawns weighing 1 g (males) and 1.5 g (females) grew to 2.3 and 3.4 g respectively in just over four months in tanks kept outdoors.
- 13 Prawns hatched in the laboratory and cultured in experiments for 15 months reached a mean size of 2.8 g. The mean loss of animals during this time was 3.2 per cent per week.

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Plate 1. Specimens of adult female *Pandalus platyceros*; total length, including rostrum, 150 mm.

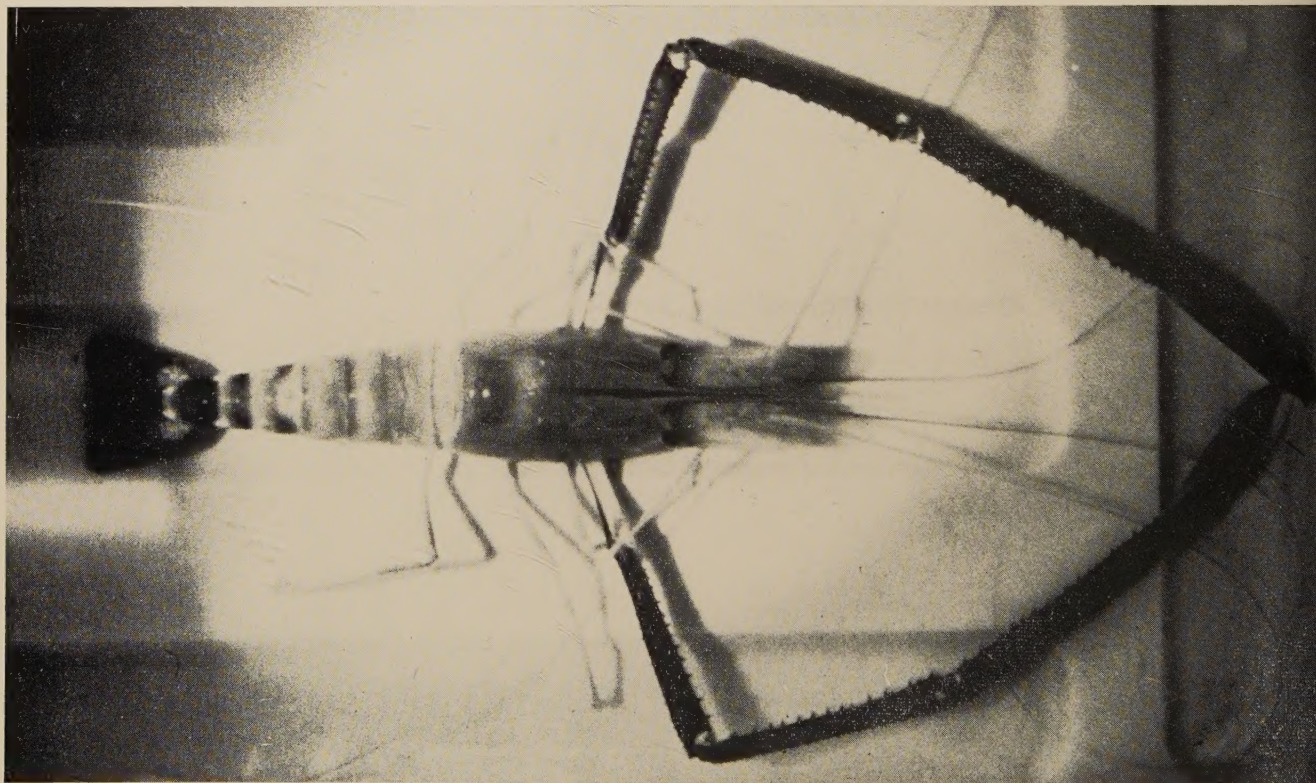


Plate 2. Male specimen of *Macrobrachium rosenbergii* aged 2 years from hatching; total length, including rostrum, 240 mm.